CHAPTER 4: AGENCY GOALS AND PERFORMANCE MEASURES

Chapter Purpose: The previous chapter discussed how a TMS performance measurement program influences an agency's vision, goals, and objectives. Chapter 4 further discusses typical performance measurement goals of TMS related agencies and also addresses, in more detail, the challenges that these agencies face with regards to a TMS performance measurement program. This chapter presents typical goals of TMS related agencies including state departments of transportation, metropolitan planning organizations, and transportation management centers. It also presents a list of performance measures organized by TMS type. Figure 4-1, on the next page, illustrates the components forming the basis of a TMS performance measurement program and shows Chapter 4 in relation to the rest of the handbook.

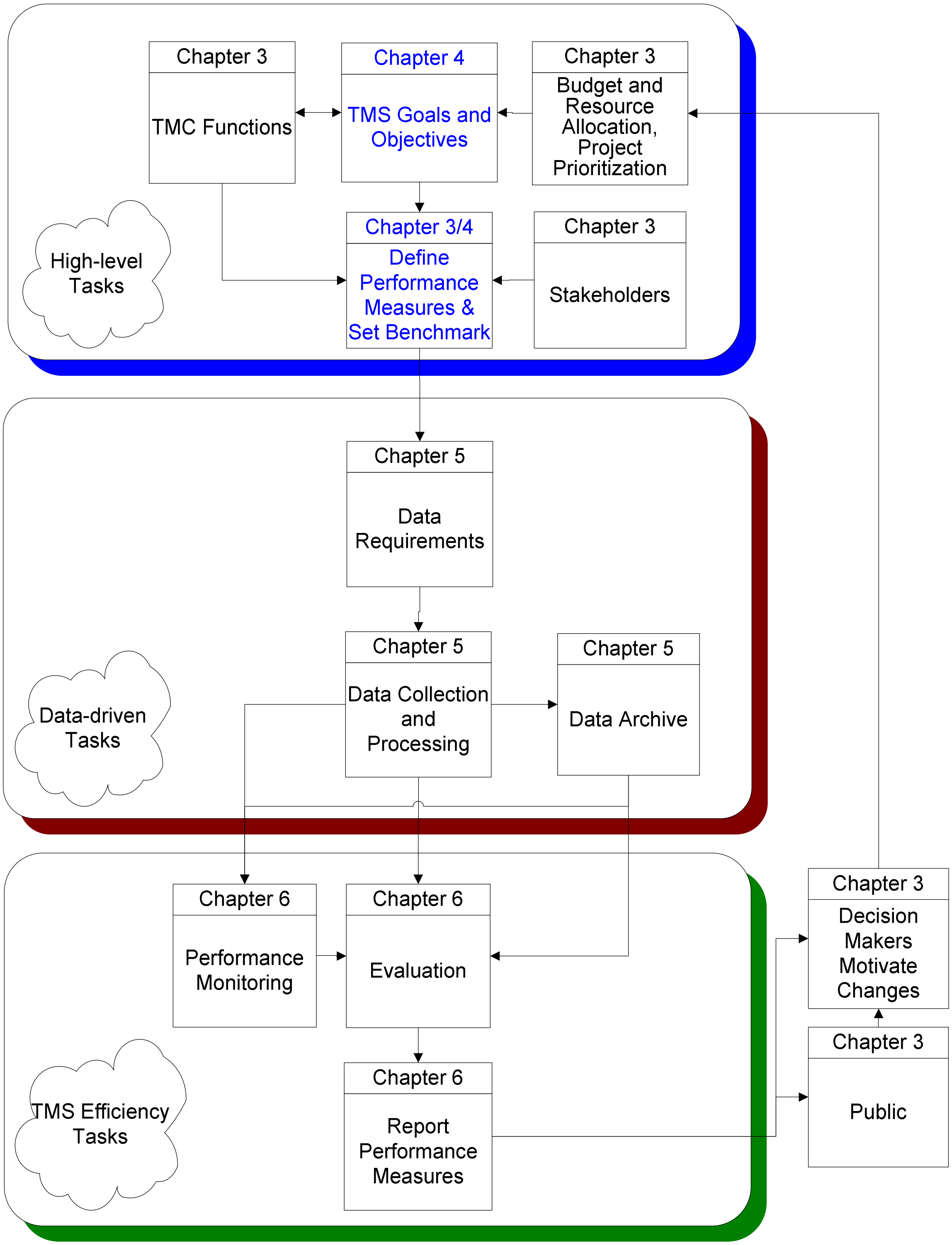

Figure 4-1: An Overview of a TMS Performance Measurement Program

4.1 TMS Related Agencies and Their Goals

This section identifies how TMS functionality may influence typical goals and measures used by public agencies, service providers, and other stakeholders. Because “a consensus does not exist and technical guidance has not been developed regarding the appropriate measures” variation exists in the performance measures used from one TMS to another (Transportation Research Board, *NCHRP Synthesis 311* 2003).

Departments of Transportation

The job of a DOT is to plan, build, maintain, and improve the state’s transportation network (Georgia Department of Transportation 2005). Typical goals of a DOT include improving efficiency, capacity, and safety. Some goals specific to state DOTs are listed in Box 4-1.

DOT-Specific Goals	
NYSDOT	One of the goals of the NYSDOT is to maintain a facility that is protected from external dangers and potential abuses.
ODOT	Ohio’s mission is to create a transportation network that connects them to the global economy.
VDOT	Virginia specifies the overall goal of achieving results on time and on budget.
RIDOT	Part of RIDOTs mission is to provide a transportation network that, in addition to meeting general goals such as safety, is both “aesthetically and culturally sensitive.”
UDOT	One of the Utah DOT’s four main goals is to increase the capacity of their transportation system.
ODOT	Improving the livability of their state through its transportation system is one of Oregon’s visions.

Box 4-1: DOT-Specific Goals (DOT individual websites)

Transportation Management Centers

The functions of a TMC include incident response, traveler information, traffic management, and video surveillance (Hudson Valley Transportation management Center). The overall purpose of a TMC is to improve mobility and safety; the general goal is to reduce incident response time and incident rates, especially secondary incidents (Sreedevi 2003). “The overall goal of [the]

Transportation Management Center is to maximize the use of the existing transportation network" (Washington State Department of Transportation 2005).

Because TMCs manage a transportation network, improved ITS and inter-agency cooperation are typical goals. Houston TranStar, for example, is a partnership of four public agencies: the Texas DOT, Harris County, the Metropolitan Transit Authority of Harris County, and the city of Houston (Houston TranStar). Minnesota created a Regional TMC to serve as a "unified communications center" for the State Patrol Dispatch, Maintenance Dispatch, and Traffic Operations to meet their coordination needs. Hudson Valley TMC, on the other hand, "recognizes that the private sector will play a critical role in ITS implementation. A priority element is to promote opportunities for ITS public/private partnerships through active participation mechanisms like ITS-AMERICA and to pursue innovative means to accomplish these new partnerships" (Hudson Valley Transportation management Center).

Metropolitan Planning Organizations

Transportation planning with the intention to secure federal funding is the main function of an MPO. A typical goal of an MPO is "to provide comprehensive, coordinated and continuous ("3C") transportation planning for the safe and efficient movement of people and goods consistent with the region's overall economic, social and environmental goals. Special emphasis is placed on providing equal access to a variety of transportation choices and effective public involvement in the transportation planning process" (San Antonio Bexar County 2005).

FHWA has recommended to MPOs the goals of accommodating bicyclists and pedestrians (Pekow), of instituting freight planning, and of improving analytic models. In general, FHWA has found MPO goal setting to be vague and there is "insufficient application of objective performance-based criteria" (Federal Highway Administration, *Breakout Session Summary Session* Comparison).

Comparison

The functional difference between a DOT and an MPO accounts for different goals and corresponding performance measures. While a DOT is concerned with the maintenance of a system, an MPO may use measures that focus more on the community, such as sustainability. Similar rifts occur between urban/rural and passenger/freight interests. For instance, while predominately rural agencies use traditional performance measures, urban agencies look for "mode-neutral" performance measures to invalidate the notion that highway investments are of a higher priority (Cambridge 1999).

The rift between urban and rural performance measure programs is partly because of size. "Agencies in larger (population) areas are more likely to have a performance measure program in place. This may be a result of the resources available to larger agencies or that these agencies have more complex congestion and mobility issues to manage that may not be adequately addressed by more traditional measures of effectiveness such as LOS." NYDOT, for example, is concerned with "external threats" to target areas along its transportation network that most rural DOTs wouldn't consider. Regional differences will also occur in areas such as weather management. The agencies in areas receiving snow and ice will be concerned with roadway conditions during bad weather and may set corresponding goals (Transportation Research Board, *NCHRP Synthesis 311* 2003).

All agencies are concerned about their ability to effect improvement in an area of measurement; however, various agencies view certain performance measures and goals more applicable than others. The importance of such measures varies across dimensions (i.e. State versus MPO, urban versus rural, passenger versus freight, etc.) "This raises the question of how to provide guidance that is both specific enough to be useful to those who already are using a performance-based approach and at the same time broad and flexible enough to be valid across such a range of perspectives." The various interests of a TMS create the added challenge of defining performance measures that are appropriate for a range of functions without losing their existing application (Cambridge 1999).

Further complication occurs when measures are imposed on a TMS by stakeholders. External obligations may interfere with an agency's own idea of important measures, even if they are flexible. One solution to this conflict of interest is to overlap sets of measures so that one set satisfies the external requirements and the other meets internal needs. Inherent in this method is an added degree of complication and confusion (TransTech 2003).

In general, it is inevitable that performance needs will vary. When conflicts occur between various performance measures, they should be acknowledged and balanced if possible. Regardless of function, agencies share the common goal of accountability. For this reason, an agency's measures should be clear and focused. They will help an agency set policies and make them more accountable their stakeholders. It is also important that selected performance measures reflect the goals of a TMS; the goals and objectives should not be influenced by the performance measures. The end result will be a measure of success that will accurately reflect the achievement of a defined objective (Neudroff et al. 2003). Box 4-2 below highlights the goals of the Utah Department of Transportation's performance-based program.

“Quality Transportation Today, Better Transportation Tomorrow.”

This is the Utah Department of Transportation (UDOT)’s motto. Each year UDOT reviews and revises their list of goals to keep on top of the current needs in their state. UDOT recently vamped up their commitment to goal setting. By asking themselves three pointed questions—Who are we? What is our focus? What do we do and how do we do it?—UDOT was able to establish four specific goals: take care of what we have, make the system work better, improve safety, and increase capacity.

Each strategic goal is subcategorized into focus areas. “Take care of what we have,” for example, is broken down to the preservation of pavement, the preservation of bridge structures, and overall maintenance efforts. Performance measures, including the performance target, are then outlined.

UDOT also initiated a Statewide Transportation Improvement Program (STIP) and is looking as far ahead as 2030 with a long range plan, Utah Transportation 2030, based on its four strategic goals. UDOT represents an agency that effectively uses goals and measures to make progress (Utah Department of Transportation).

Box 4-2: Example of the application of performance measures to achieve goals (Utah Department of Transportation)

4.2 Typical TMS Performance Measures

This section provides standard measures that can be applied to typical TMS functions in order to meet the goals and objectives of a TMS. Tables 4-1, 4-2, and 4-3 are categorized by TMS type and its respective functions. Three types of TMSs are considered: freeway, arterial, and transit. They are organized further by functions and also by input, output, outcome, and external measures. Please see Figure 4-2, on the next page, for a holistic view of the TMC types and functions. It is noted that some of performance measures presented in this section can be used independently, while some measures need to be used with conjunction with other performance measures. For example, the measure of the number of cameras itself is useless. However, it becomes meaningful when used with the coverage miles.

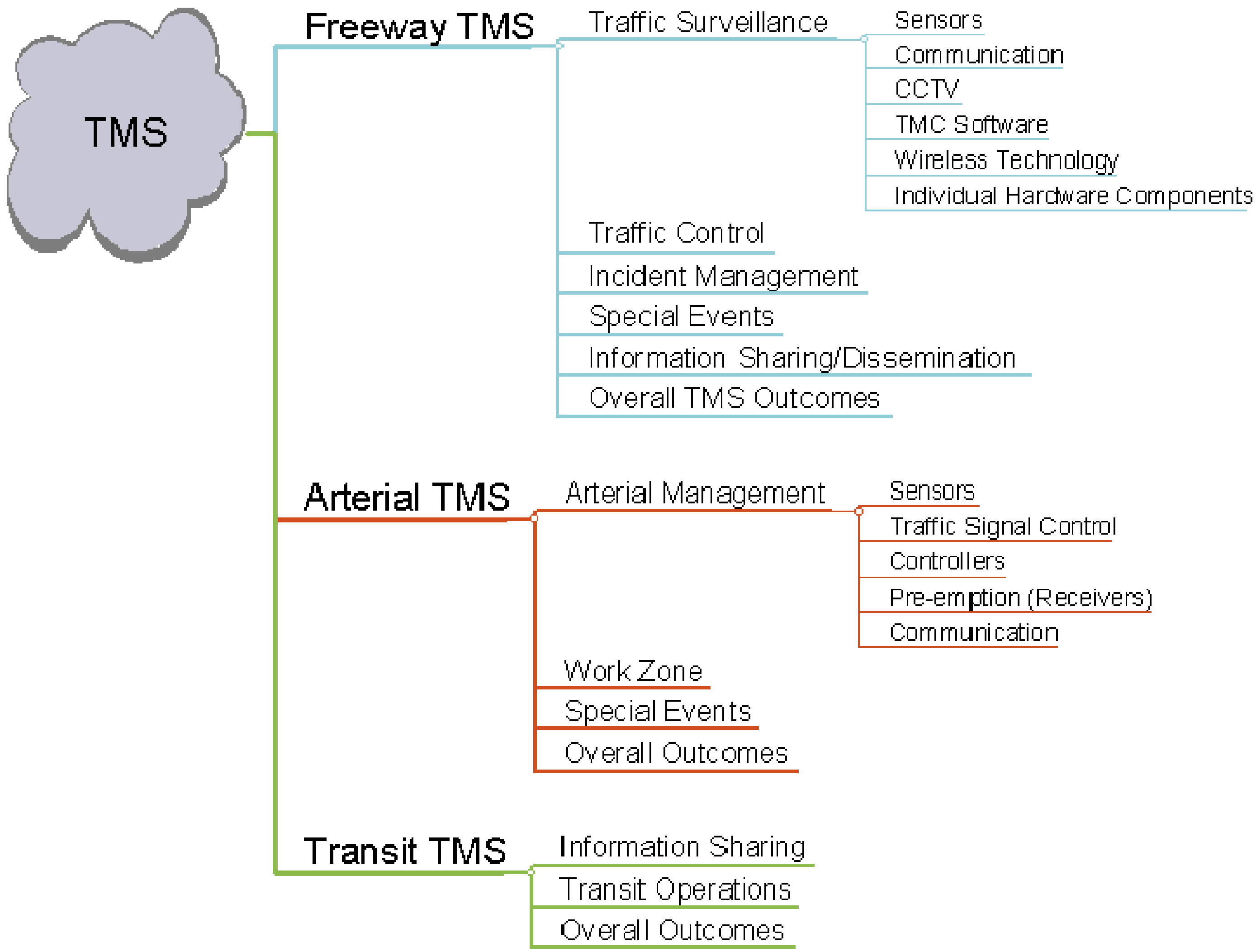

Figure 4-2: Overview of TMSs by Type and Their Respective Functions

Table 4-1: Performance Measures Corresponding to a Freeway TMS

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Traffic Surveillance	Sensors	Person-hours spent working on installation / maintenance	Input		
		Percent time working properly	Output		
		Percent freeway miles with electronic data collection	Output	Can be an external factor for analysis	$\frac{\text{Freeway Miles With Data Collection}}{\text{Total Freeway Miles}} \times 100\%$
		Number of loop/video/AVL/AVI readers working properly	Output	Can be an external factor for analysis	
		Spacing between sensors	Output	Can be an external factor for analysis	Average for n spacings, $\frac{\sum_{i=1}^{n} Spacing_i}{n}$
		Data quality, reliability by detector, other hardware, software algorithms, sensor type	Output		
	Communication	Efficiency of bandwidth	Input		$Efficiency = \frac{Bandwidth}{CycleLength} \times 100\%$
		Speed[8]	Output		see page 29
		Number of bits lost (i.e. noise)	Output		
		Number or percentage of time of failures	Output	Defined as complete loss of communication	
	CCTV	Person-hours spent working on CCTV system	Input		
		Percent time working properly	Output		
	Software at TMC	Person-hours spent working on TMC software maintenance and upgrades	Input		
		Flexibility	Output	Ease/cost of expansion to include new VMS, sensors, CCTV, etc.	
		Interoperability	Output	With other software used frequently at the TMC such as internet, etc.	
		Reliability[10]	Output		see page 31
		Other issues (maintainability, security, integration etc.)	Output		
		Number of service calls related to software	Output		

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Traffic Surveillance	Wireless Technologies	Market penetration	Output	Can be an external factor for analysis	
		Number and location of readers by type (AVL, license plate, toll tags etc.)	Output		
	Individual Hardware Components	Person-hours working on component monitoring and maintenance	Input	Can also use dollars spent as measure	
		Frequency of checking the status of the sensors	Output	Including sensors, readers, CCTV, video walls, hardware/software components, switches, routers, computer stations, servers, communication lines	
		Percent of time, and number of components working properly	Output		$\frac{\text{Time Component Works Properly}}{\text{Total Operation Time For Component}} \times 100\%$
		Equipment Downtime	Output	Percent time component not working, and percent time component working incorrectly (to help diagnosis)	$\frac{\textit{Time Equipment Broken}}{\textit{Total Operation Time For Equipment}} \times 100\%$
		Mean time between equipment failure	Output		$\frac{\sum_{i+1}^{n} \textit{Time Between Failures}_i}{n}$
Traffic Control	General	Person-hours spent working on system	Input		
		Total/Percent freeway miles with electronic data collection	Input	Output for traffic surveillance	
		Number of loop/video/AVL/AVI readers	Input	Output for traffic surveillance	
		Spacing between sensors	Input	Output for traffic surveillance	Average for n spacings, $\frac{\sum_{i=1}^{n} \textit{Spacing}_i}{n}$
		Data quality, reliability by detector, other hardware, software algorithms, sensor type	Input	Output for traffic surveillance	

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Traffic Control	HOV/Ramp Metering/Other Controls	Person-hours spent toward HOV/ramp metering/other management	Input		
		Percent of equipment (sensors, ramp meters, etc.) in "good" (working) condition	Output		$\frac{No.\ of\ Pieces\ \ Working}{Total\ \ No.\ of\ Pieces} \times 100\%$
		Percent time VMS working properly	Output		$\frac{Time\ \ VMS\ \ Working}{Total\ \ Operation\ \ \ Time} \times 100\%$
		Percent time RHOV (or HOV) gates working properly	Output		$\frac{Time\ \ RHOV\ \ Gates\ \ Working}{Total\ \ Operation\ \ Time} \times 100\%$
		Percent time Lane Control Systems (LCS) working properly	Output	Where lane control opens/closes lanes/shoulders for use	$\frac{Time\ \ \ LCS\ \ \ Working}{Total\ \ \ Operation\ \ \ \ Time} \times 100\%$
		Number of hours that ramp metering is in operation	Output		
		Percent time ramp metering working properly	Output		$\frac{Time\ \ Ramp\ \ Metering\ \ Working}{Total\ \ Operation\ \ Time} \times 100\%$
		Frequency of ramp metering software algorithm review/evaluation	Output	To measure currency/outdatedness	
		Frequency of updating ramp metering rate	Output		
		HOV vs. general purpose travel time	Outcome		
	Evacuation	Number of evacuation events	External		
		Extent of coordination with other agencies	Input	i.e., law enforcement and EMS	$\frac{No.\ Incidents\ \ Managed\ \ Jointly}{Total\ \ No.\ Incidents\ \ Managed} \times 100\%$
		Available number of personnel trained in evacuation operations	Input	In field and in TMC	
		Number of signs (both VMS and Static) - installed, checked, maintained in working condition	Input/output		

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Traffic Control	Evacuation	Time required to disseminate information to VMS/HAR	Output		Average for n disseminations, $\frac{\sum_{i=1}^{n} Time\ to\ Disseminate_i}{n}$
		Frequency of update/review of evacuation plans/routes/signs	Output		$No.\ Update/Review\ per\ Quarter\ or\ Year$
	Weather	Hours, lane-miles, lane-mile-hours affected by (applicable) severe weather (rain, snow, ice, surface ice, high winds, fog, dust, smoke)	External	For before-and-after studies	
		Person-hours spent toward weather events	Input		
		Lane-miles pre-treated/plowed per hour/day (for snow events)	Output		$\frac{No.\ Lane\ Miles\ Treated}{Hour\ or\ Day}$
		Percent of equipment (e.g., snow plow) working	Output		$\frac{No.\ of\ Pieces\ Working}{Total\ No.\ of\ Pieces} \times 100\%$
		Number of messages displayed on changeable message signs, per weather event	Output		Average for n events, $\frac{\sum_{i=1}^{n} No.\ of\ Messages_i}{n}$
		Number of weather events for which messages were displayed vs. total weather events	Output		$\frac{No.\ of\ Events\ With\ Messages\ Displayed}{Total\ No.\ of\ Events}$
	Human Component	Turnover rate	External/output	Depends if the quality of work environment is objective of agency	$\frac{No.\ People\ that\ Left\ Job}{Total\ No.\ People\ at\ Job} \times 100\%$
		Person-hours working	Input	In field and in TMC, by job description	$No.\ People\ Working \times \frac{Avg\ Working\ Hours}{Day\ or\ Year}$
		Job experience/skills	Input		
		Dollar amount spent on employee training	Input	Summed over time (per month, per quarter, per year), or an average dollar amount per employee	Average, $\frac{Total\ Dollars\ Spent\ On\ Training}{No.\ of\ Employees\ Trained}$

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Traffic Control	Human Component	Quality of Training provided for personnel	Input	For multi-tasking, interpersonal coordination with other agencies, customer service, other traffic control reviews	
		Number of human errors	Output		
Incident Management	General	Number of incidents, by severity (e.g., fatal, injury), by type (e.g., crash, stalled vehicle)[2]	External	See page 26	
		Person-hours working for TMS Incident Management System	Input	Both in field and in TMC	
		Number of responded crashes versus total number of crashes	Output	Responded crashes are crashes responded to by State Safety Patrol or Freeway Incident Response Team	$\frac{No.\ of\ Responded\ Crashes}{Total\ No.\ of\ Crashes\ Reported}$
		Response time to incidents[1]	Output	See page 26	
	Sensors	Percent time working properly	External	Also an output for traffic surveillance	
		Percent freeway miles with electronic data collection	External	Also an output for traffic surveillance	$\frac{Freeway\ Miles\ With\ Data\ Collection}{Total\ Freeway\ Miles} \times 100\%$
		Sensor Downtime	Input	Percent time component not working, and percent time component working incorrectly	$\frac{Time\ Sensor\ Not\ Working}{Total\ Operation\ Time} \times 100\%$
	Calls	Number of employees/person-hours answering calls	Input		
		Incident-related calls	Input/output	Input for incident, output for calls	
		Number of incidents detected and/or verified with calls vs. the total number of incidents detected and verified	Output		$Total\ No.\ Incident\ Calls$ - ... - $[Duplicate + False\ Alarm\ Calls]$
	Incident Detection Algorithms (Software)	Percent time component working properly	Input	Output for traffic surveillance	$\frac{Time\ Component\ Working}{Total\ Operation\ Time} \times 100\%$
		Incident detection Rate[3]	Output	see page 26	
		False Alarm Rate (FAR)[3]	Output	see page 26	

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Incident Management	Incident Detection Algorithms (Software)	Mean Time to Detect (MTTD) incidents	Output		For n incidents, $\frac{\sum_{i+1}^{n} Incident\ Detection\ Time_i}{n}$
	CCTV	Number of surveillance cameras	Input	Output for surveillance	
		Roadway coverage	Input	Output for surveillance	$\frac{No.\ of\ Lane\ Miles\ Monitored\ By\ CCTVs}{No.\ of\ Lane\ Miles\ Managed}$
		Percent of time CCTVs working properly	Input	Output for surveillance	$\frac{Time\ CCTVs\ Working}{Total\ Operation\ Time} \times 100\%$
		Number of identified incidents using CCTV	Output		
	EMS & Safety Patrol	Total number of EMS/Safety Patrol vehicles	Input	Need to define coverage hours (by time of day, day of the week, or special event)	
		Safety vehicle mileages per year	Input		Total for n safety vehicles, $\frac{\sum_{i=1}^{n} MileageofSafetyVehicle_i}{Year}$
		Average duration of lanes, shoulders closed by incident type/severity	Output	Correlates to the system's relibability (important for budgeting resources and response procedures) Example: plot the likelihood of lane closure by location and by hour of the week to organize responder resources	Average for n incidents, $\frac{\sum_{i=1}^{n} Duration\ Lanes,\ Shoulders\ Closed_i}{n}$
		Response time by incident type/severity[1]	Output	see page 26	
		Clearance time by incident type/severity[5]	Output	see page 27	
		On-scene time	Output	The time EMS and/or safety crew spends at the incident site	
	VMS/HAR/511	Percent of time VMS working properly	Input		$\frac{Time\ VMS\ Working}{Total\ Operation\ Time} \times 100\%$
		Time required to program a new VMS message	Output	The time taken to post an incident-related message	Average for n messages, $\frac{\sum_{i=1}^{n} Time\ to\ Program\ Message_i}{n}$
		Effectiveness of message	Output	From customer surveys/calls	

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Incident Management	Verification	Person-hours working on verification	Input		
		Verification time[4]	Output	see page 27	
	Outcomes	Total or average hours of incident-related delay	Outcome		
		Number of secondary crashes per primary crash	Outcome		
Special Events	Planned Events	Number of events per month	External		
		Number, duration of lanes/shoulder miles closed, by event type	External		Average duration for n events, $\frac{\sum_{i=1}^{n} Duration\ Lanes,\ Shoulders\ Closed_i}{n}$
		Person-hours working on planned event management	Input		
		Volume of traffic on major routes, alternate routes	Output		$\frac{No.\ Vehicles\ on\ Major/Alternate\ Route}{Hour}$
		Volume of traffic entering and exiting the site and parking areas	Output		$\frac{No.\ Vehicles\ Entering/Exiting}{Hour}$
		Number of event patrons and participants utilizing transit to and from the event	Output		
		Average vehicle occupancy	Output		For n vehicles, $\frac{\sum_{i=1}^{n} Vehicle\ Occupancy_i}{n}$
		Percent time VMS working properly (and other VMS related measures)	Output		$\frac{Time\ VMS\ Working\ Properly}{Total\ Operation\ Time} \times 100\,\%$
		Number of messages displayed per VMS, and time periods of messages	Output	To evaluate the locations of VMSs (usefulness) Example: find optimal number of messages and length of time they are displayed so that they can all be read, and optimal location to get travelers' attention	Average for n messages, $\frac{\sum_{i+1}^{n} Time\ Between\ Failures_i}{n}$ $\frac{\sum_{i=1}^{n} Time\ Message\ Displayed_i}{n}$
		Clarity, accuracy, timeliness of messages, per event	Output	Customer surveys	

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Special Events	Planned Events	Number of messages broadcast on highway advisory radio or other media	Output		
		Number of messages transmitted among agencies	Output	Indicates coordination, clarity of messages	
		Frequency of evaluating/changing regular traffic signal timing for special events	Output		
		Number of times a ramp(s) was closed and time/duration of closure(s)	Output		Average duration for n closures, $\frac{\sum_{i=1}^{n} Amount\ of\ Time\ Closed_i}{n}$
	Work Zone	Number, lane miles, time periods of work zones, by type	External		
		Miles, hours of lanes/shoulders closed due to work zones, by type and capacity reduction	External	Average, range (minimum, maximum), median, and variance	
		Work zone configuration	External/output	Time of day, partial closures, etc.	
		Person-hours spent working on system	Input	Can also use dollars spent as measure	
		VMT exposed to work zones of different types	Output		
		Average time for work completion, by work zone type	Output		For n work zones of one type, $\frac{\sum_{i=1}^{n} Time\ to\ Complete_i}{n}$
		Number of work zone crashes	Output		
	Outcomes	Number of reduced crashes	Outcome		
		Travel times	Outcome		
		Hours of delay	Outcome		
		Capacity reductions	Outcome		$\frac{Vehicles\ per\ Hour}{(Vehicles\ per\ Hour)_{max}} \times 100\%$

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Information Sharing/ Dissemination	General	Person-hours spent on overall information sharing/dissemination	Input		
		Amount spent on hardware/software system components	Input		
	Real-Time	Person-hours spent on real-time information sharing/dissemination	Input		
		Frequency of data sharing (crash, planned events, weather, traffic) with EMS, transit, and signal system TMS	Output	i.e. how often is applicable information shared Example: informing EMS of a concert event so they can mobilize resources	$No.\ of\ Data\ Sharing\ per\ Month\ or\ Year$
		Number of agencies that receive information	Output	For identification and inclusion of agencies wanting traffic-related data	
		Extent of real-time information (lane-miles or intersections) available/shared	Output		$\frac{Real\ Time\ Coverage\ (Lane-Miles)}{Total\ Coverage\ (Lane-Miles)}$ $\frac{No.\ Intersections\ with\ Real\ Time\ Information}{Total\ No.\ Intersections}$
		Frequency/duration of radio broadcasts	Output		Average duration for n broadcasts, $\frac{No.\ of\ Traffic\ Broadcasts}{Time}\times 100\%$ $\frac{\sum_{i=1}^{n} Time_i}{n}$
		Individuals receiving traveler information by source (511, other direct means)	Output	Customer survey	
		Percent of road closures communicated to public within certain period of closing	Output		$\frac{Communicated\ Road\ Closures}{Total\ Road\ Closures}\times 100\%$
		Hits per day on traveler information web site	Output		Average for n days, $\frac{\sum_{i=1}^{n} No.\ of\ Hits_i}{n}$
		Information quality perceived by customers	Output	Real-time and off-line	

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Information Sharing/ Dissemination	Off-Line	Person-hours spent working on off-line activities	Input		
		Frequency of offline system update	Output	On an as-needed basis	
		System update frequency by components	Output		
		Number of newsletter subscribers	Output		
		Number of ways to access information	Output	Improved on an as-available technological basis	
		Number of people/organizations accessing information	Output		
		Speed of results returned for a query	Output	Qualitatively measured as acceptable or unacceptable speeds	Average for n queries, $\frac{\sum_{i=1}^{n} Time\ to\ Return\ Results_i}{n}$
		Number of users/visits to websites	Output		
		Number of queries	Output		
		Total amount of data queried	Output		
	Outcomes	Reduced overall travel time	Outcome		
		Reduced overall delay	Outcome		
		Customer satisfaction	Outcome		
Overall TMS Outcomes	Mobility6	VMT by congestion level	Outcome		
		Delay due to congestion (total or by vehicle)[7]	Outcome		see page 28; Average for n events, $\frac{\sum_{i=1}^{n} Delay/Lost\ Time_i}{n}$
		Level of service or volume-to-capacity ratios	Outcome	Classified A (best) to F (worst)	$\frac{Volume}{Capacity}$
		Duration of congestion (lane-mile/hours in LOS E or F)	Outcome	The maximum length of time a segment of the facility is congested	
		Percent of system congested	Outcome	Often correlates with LOS E or F	$\frac{Lane\ Miles\ Congested}{Total\ Lane\ Miles} \times 100\%$
		Percent of miles operating in desired speed range	Outcome		
		Average speed[8]	Outcome		see page 29
		Travel time[9]	Outcome		see page 30

Freeway System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Overall TMS Outcomes	Mobility6	Travel Time Reliability[10]	Outcome	Variability and range in travel times, percent of acceptable times	see page 31
		Indices such as Travel Time Index, Buffer Index, Travel Rate Index[11]	Outcome	Based on Urban Mobility Program measures	see page 33
	Safety	Total number of crashes (property damage, injuries, fatalitites)	Outcome	Both an external factor and an outcome, based on whether or not avoidable by a TMS	
		Construction-related fatalities	Outcome		$\frac{\text{No. of Fatalities in Work Zones}}{\text{Total No. Fatalities}} \times 100\%$
		Number of secondary crashes	Outcome		
	Customer Satisfaction	Customer perception of safety	Outcome	Customer surveys	
		Customer satisfaction	Outcome	Customer surveys	
		Customer perceptions on travel times	Outcome	Customer surveys	
		Estimated diversion rate	Outcome		$\frac{\text{No. Vehicles Diverted to Alt. Routes}}{\text{No. Cars in Traffic on Route of Interest}}$
		Hours of both recurring and non-recurring delay by mode	Outcome	Non-recurring delay correlates to incident-related delay	
	Quantity of Travel	Total person-hours traveled by vehicle type	Outcome		
		Average delay (total, recurring, & incident – based)	Outcome		
	System Utilization	Density (passenger cars per hour per lane)	Outcome		*No. of Passenger Cars/hour/ lane*
		Percentage of travel heavily congested	Outcome		$\frac{\text{Miles of Heavily Congested Travel}}{\text{Total Miles Traveled}} \times 100\%$
		V/C ratio	Outcome		$\frac{\text{Volume}}{\text{Capacity}}$
	Queue Characteristics	Queue growth rate	Outcome		$\frac{\text{Cum. Arrival - Cum. Departure}}{\text{Time}}$
		Queue length (average or maximum)	Outcome		*Cum. Arrival - Cum. Departure*

Table 4-2: Performance Measures Corresponding to an Arterial TMS

Arterial System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Arterial Management	Sensors	Total intersections, corridors	External		
		Number of personnel available and hours spent on activities (e.g., operation, maintenace, etc.)	Input		
		Maintenance (hours, cost) spent on field equipment (total and average)	Input		
		Links of coverage vs. total links	Output		
		Data quality, accuracy, reliability by sensor type and other components	Output		
		Equipment downtime	Output	Percent time component not working, and percent time component working incorrectly (helps in diagnosis)	$\frac{Time\ \ Equipment\ \ \ Not\ \ Working}{Total\ \ Operation\ \ \ Time} \times 100\ \%$
		Frequency of checking the status of the sensors	Output		
		Mean Time Between Failures (MTBF) for field equipment	Output		$\frac{\sum_{i=1}^{n} TimeBetwee\ \ enFailure_{\ i}}{n}$
		Number of routine maintenance calls per time period	Output		
	Traffic Signal Control	Cost of updating timing plan, per intersection/corridor	External		Average for n updates, per intersection/corridor, $\frac{\sum_{i=1}^{n} Cost_{\ i}}{n}$
		Person-hours toward traffic signal control	Input	Can also use dollars spent as metric	
		Number of signals to be maintained per person	Input		$\frac{No.SignalsToM\ a\,\mathrm{int}\ ain}{No.PeopleMa\ \ \mathrm{int}\ aining}$
		Number of maintained signals vs. total signals	Output		

Arterial System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Arterial Management	Controllers	Change in intersection approach volumes	External		
		Person-hours spent toward maintaining/operating for controllers	Input	Can also use dollars spent as metric	
		Time taken to replace or repair failed equipment	Input / Output		Average for n replacement/repairs, $\frac{\sum_{i=1}^{n} Maintenance\ Cost_i}{n}$ $\frac{\sum_{i=1}^{n} Time_i}{n}$
		Frequency of reviewing timing plan, per intersection/corridor	Output	Note the difference between reviewing and retiming	
		Number of signals retimed per given time period	Output		
		Frequency of failures (flash mode or complete failure)	Output	Due to power outage or broken lights	
		Frequency of resetting clock due to shifting	Output		
		Time/cost required for uploading new timing plan to controller	Output		
		Utilization of capabilities within controller software (transition logic, transit signal priority, etc.)	Output		
	Pre-Emption (Receivers)	Number of vehicles equipped with receivers	External		
		Person-hours working on pre-emption management	Input		
		Percent of time not working properly	Output		$\frac{Time\ Receiver\ Not\ Working}{Total\ Operation\ Time}$
		Number of actual services/month	Output	Indicated by the actuations on the receiver	
	Communication	Bandwidth	Input		
		Speed[8]	Output		see page 29
		Number of bits lost (i.e. noise)	Output		

Arterial System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Arterial Management	Communication	Number or percentage of time of failures	Output	Complete loss of communication	$\frac{\text{No. Failures}}{\text{Day/Month}}$
Work Zone		Number, lane miles, turning movement closures, intersection closures, time periods of work zones, by type	External		
		Intersection capacity, lane number, hours or miles, closed due to work zones of different types	External		$\frac{\text{No. Lane Number/Miles/Hours Closed}}{\text{Total Lane Number/Miles/Hours}}$
		Number of work zones per month	External		$\frac{\text{No. Work Zones}}{\text{Month}}$
		Vehicles, VMT exposed to work zones	External/output	Type depends on the use of work zone configuration	
		Average (duration, length) of work zones by types	External/output	Type depends on the use of work zone configuration	Average for n work zones, $\frac{\sum_{i=1}^{n} \text{Length of Work Zone}_i}{n}$
		Average time for work completion, by work zone type	External/output	Type depends on the use of work zone configuration	Average for n work zones, $\frac{\sum_{i=1}^{n} \text{Time for Work Completion}_i}{n}$
		Work zone configuration	External/output	Time of day, partial closures, etc.	
		Work zone requests	Input		
		Person-hours spent on work zone configuration & implementation	Input		
		Frequency, number of work-zone crashes	Output		$\frac{\text{No. Work Zone Crashes}}{\text{Day/Month}}$
		Percent time VMS working properly (and other VMS related measures, where applicable)	Output		$\frac{\text{Time VMS Working}}{\text{Total Operation Time}} \times 100\%$
Special Events		Number of events	External		
		Duration of event	External		
		Person-hours toward special event work	Input	Can also use dollars spent as metric	

Arterial System					
Function Category	**Components**	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Special Events		Frequency of evaluating/changing timing plans for special events	Output		*No. reviews per event*
		Number of special event signal operations by time of day, day of week and event types	Output		
		Coordination level with freeway TMSs and other jurisdiction signal systems	Output	Depending on the need to review	
Overall Measures		Total lane-miles being managed	External		
		Person-hours toward arterial management	Input		
		Number of cycle failures, per intersection/corridor	Output	Classified by cause of failure (poor timings or excessive demand)	$\frac{\text{No. Cycle Failures}}{\text{Day/Month}}$
		Efficiency of bandwidth	Output		$Efficiency = \frac{Bandwidth}{CycleLength} \times 100\%$
		Travel time delay[7]	Outcome		see page 28
		Maximum queue length	Outcome		*Cum. Arrival - Cum. Departure*
		Customer satisfaction	Outcome		
		Number of positive/negative feedback calls vs. total calls	Outcome		$\frac{\text{No. Feedback Calls Received}}{\text{Total Calls Received}}$
		Average speeds along corridors	Outcome		Average for n vehicles, $\frac{\sum_{i=1}^{n} Speed_i}{n}$
		Travel time reliability[10]	Outcome		see page 31
		Level of service by intersection/corridor	Outcome		

Table 4-3: Performance Measures Corresponding to a Transit TMS

Transit System				
Function Category	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Information Sharing	Person-hours spent on information sharing	Input	Can also be in dollars spent	
	Number of VMS signs capable of providing information on arrivals, & % working units.	Output		$\frac{\text{No. VMS Capable of Displaying Arrivals}}{\text{Total No. VMS}}$ $\frac{No.VMSWorking}{TotalNo.VMS} \times 100\%$
	Coordination with regional TMS (Freeways, arterials, and other transit)	Output		
	Percent of time information is accurate	Output		
	Percent of time information is timely	Output		
	Percent of time information is useful	Output		
Transit Operations	Number of passengers/time period	External		
	Person-hours spent on transit operations	Input		
	Frequency of scheduling update	Output		
	Average occupancy	Output		
	On-time percentage	Output	An output in terms of systematic inefficiencies, an outcome from the customer perspective	$\frac{\text{No. On-Time Routes}}{\text{No. Routes per Day}}$
	Number of incidents, & preventive maintenance undertaken	Output		
	Percent of AVL equipped buses	Output		$\frac{No.BusesWithAVL}{TotalNo.Buses} \times 100\%$
	Proportion of buses with signal priority	Output		$\frac{\text{No. Buses with Signal Priority}}{\text{Total No. Buses}}$

Transit System				
Function Category	**Metric**	**Type**	**Supplementary Notes**	**Calculation Example(s)**
Transit Operations	Number of intersections/routes equipped with transit signal priority equipment versus total number on transit routes	Output	Requires coordination with the city/county/MPOs	
	System penetration of transit signal priority	Output		$\frac{\textit{No. Intersections/Routes with Signal Priority}}{\textit{Total No. Intersections/Routes}}$
	Number of buses out of service/route	Output		
Overall Outcomes	Customer satisfaction	Outcome		
	Travel time reduction	Outcome		
	Delay savings	Outcome		

1) *Response time* is the time it takes to activate, coordinate, and dispatch the necessary personnel, equipment, and communications once the occurrence of an incident is verified. The time ends when the first responder arrives on the scene of the incident (Neudroff et al. 2003). The relation of response time to incident management overall is shown in Figure 4-3. The time it takes to respond to an incident can be broken down by the type and severity of an incident. (This measure should have the review and recommendations of legal department before implementation to limit vulnerability to litigation.)

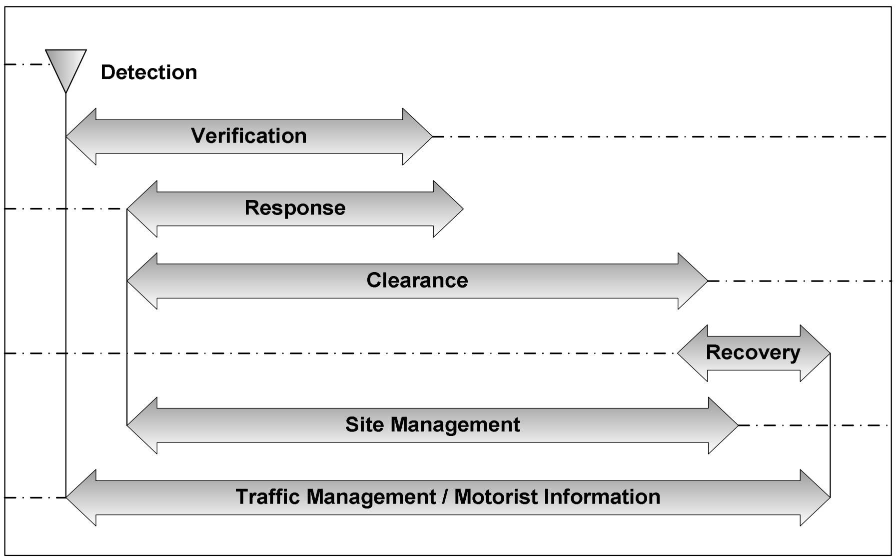

Figure 4-3: The Stages of Incident Management (Neudroff et al. 2003)

2) An incident is anything that interrupts the usual flow of traffic and can vary in type from vehicle breakdowns, to vehicle crashes, to obstructions in the roadway, such as cargo spills or fallen debris. Crashes can be subcategorized into single vehicle crashes, multiple vehicle crashes, crashes involving trucks, and weather related crashes. Severity is based on injuries and fatalities (ITS Decision 2003).

3) *Incident detection rate* and *false alarm rate (FAR)* are used to measure the performance of incident detection algorithms. The detection rate can be taken as the percentage of incidents detected by the software versus the number of incidents that occur. The FAR can be taken as the percentage of false alarms versus the number of tests run by the software. Factors that may affect the performance of an incident detection algorithm include: the operating conditions of the roadway (at or below capacity), the duration and severity of the incident, the geometric characteristics of the roadway (grade, change in the number of lanes, presence of ramps), weather (including the condition of the road surface as wet or dry), detector spacing, the location of the incident with respect to a detector, and the diversity of the traveling vehicles (ITS Decision 2003).

4) *Verification time* is the time it takes to confirm an incident has taken place and to then communicate the location and nature of an incident to the appropriate agency (Neudroff et al. 2003). Verification can generally be considered complete when the first response team arrives at the scene. An exception is when hazardous material is involved (PB Farradyne 2000). Its relation to incident clearance is shown in Figure 4-3. To measure verification time accurately, times should be recorded by TMC field personnel and by a reliable, non-TMC source for comparison.

5) *Clearance time* is measured as the time it takes to clear the vehicles, wreckage, or other obstructions that are disrupting traffic flow to return the roadway to its normal flow pattern. This may include repairs to the roadway (PB Farrdyne 2000). Clearance time should be measured according to the type and severity of the incident; the expected clearance time for a minor incident should be under 30 minutes, between 30 minutes and 2 hours for an intermediate incident, and over 2 hours for a major incident. Details of an incident are an important consideration because variables such as "truck involvement, overturned vehicles, trailer or tanker damage, fuel spills, cargo spills, fatalities, police crime scene designations, weather, travel lanes affected, and volume of passing traffic" can greatly affect the clearance time (Transportation Research Board, *NCHRP Synthesis 318*). In measuring clearance time, an agency may use notification time, actual time, or verification time as the start time. It's simply important to define these parameters. Clearance can be considered complete when the traffic bottleneck has cleared.

6) "*Mobility* is defined as the ability to satisfy the demand to move a person or goods and can be described by four parameters:

- Quantity of travel (number of persons served)
- Quality of travel (travelers' satisfaction with travel).
- Accessibility of travel (ability to reach the destination and mode choice).
- Utilization of a facility or service (the quantity of operations with respect to capacity)" (Transportation Research Board, *NCHRP Synthesis 311* 2003).

Table 4-4 is an example of Florida's Mobility Performance Measures Program and specifically the mobility performance measures in place there (Florida 2000). Some of these measures are discussed in more detail in the remainder of this section. *Mobility* measures have been used for many purposes, "ranging from site-specific operations analysis to corridor-level alternative investments analysis to area-wide planning and public information studies. Transportation agencies have adapted a wide range of mobility performance measures and these have been reviewed to develop the performance measures most appropriate for national mobility monitoring" (Battelle et al., 2002).

Dimension of Mobility	Mobility Performance Measures	State Highway System	Florida Intrastate Highway System	Florida Intrastate Highway System Corridors	Metropolitan Highway Systems	Definitions[1]
Quantity of Travel	Person miles traveled	•	•	•	•	AADT * length * vehicle occupancy
	Truck miles traveled	•	•	•	•	AADT * length * % trucks
	Vehicle miles traveled	•	•	•	•	AADT * length
	Person trips				•	Total person trips
Quality of Travel	Average speed	•	•	•		Average speed[2] weighted by PMT
	Delay	•	•	•	•	Average delay
	Average travel time			•		Distance / speed[2]
	Average trip time				•	Door to door trip travel time
	Reliability			•	•	% of travel times that are acceptable
	Maneuverability			•		Vehicles per hour per lane
Accessibility	Connectivity to intermodal facilities	•	•	•	•	% within 5 miles (1 mile for metropolitan)
	Dwelling unit proximity		•	•	•	% within 5 miles (1 mile for metropolitan)
	Employment proximity		•	•	•	% within 5 miles (1 mile for metropolitan)
	Industrial/warehouse facility proximity		•			% within 5 miles
	% miles bicycle accomodations	•			•	% miles with bike lane/shoulder coverage
	% miles pedestrain accomodations	•			•	% miles with sidewalk coverage
Utilization	% system heavily congested	•	•	•	•	% miles at LOS E or F
	% travel heavily congested	•	•	•	•	% daily VMT at LOS E or F
	Vehicles per lane mile	•	•	•	•	AADT * length / lane miles
	Duration of congestion	•	•	•	•	Lane-miles-hours at LOS E or F

[1] Definitions shown are generally for daily analysis. Calculations for the peak are based on prevailing conditions during the typical weekeday 5:00 to 6:00 PM peak.
[2] Speed based on models using the HCM or field data.

Table 4-4: Florida's Mobility Performance Measures for Highways (Florida 2000)

7) *Delay* is added travel time caused by congestion. It can be calculated as:

Equation 4-1

$$\begin{aligned} &\textit{Total Segment Delay (veh-min)} = [\textit{Actual Acceptable Travel Time (min)} - \\ &\textit{Actual Travel Time (min)}] \times \textit{Volume (veh)}, \end{aligned}$$

$$\textit{Total Delay (veh-min)} = \sum_{i=1}^{n} \textit{Segment Delay}_i$$

Acceptable travel time for expected conditions is generally based on the posted speed limit, but may "be calculated using a congestion threshold speed established from local performance goals for mobility." "Acceptable travel conditions" are usually free-flow (Federal Highway Administration 2002).

Another method is to measure the divergence of the actual travel time from the expected travel time. Equation 4-2 can be used to calculate delay over a set of links assuming free-flow conditions.

Equation 4-2

$$D = \sum_{i=1}^{n} L_i \times F_i(t) \times \left[\frac{1}{V_i} - \frac{1}{f_i} \right]$$

Where,

L_i = The length of the ith segment holding the ith TMS, which can be derived from adjacent TMS' locations marked by milepost value

$F_i(t)$ = The total volume at the ith TMS site for the specified period t

f_i = The free-flow speed at the ith segment (Martin 2003)

8) *Average Speed* is the arithmetic average of all vehicles for a specified period of time. The simplest calculation is to take distance over time: total distance traveled divided by the total time to travel "x" distance. Because TMS data is collected by lane, weighting factors based on the volume in each lane are used to determine the average speed at a given point in all lanes. The lane with the highest volume is given the highest weight. Equation 4-3 represents this method (Martin 2003).

Equation 4-3

$$V^i = \frac{\sum_{m=1}^{n} F^i{}_{Dm} V^i{}_{Dm}}{\sum_{m=1}^{n} F^i{}_{Dm}}$$

Where,

V^i = Weighted average speed at the ith TMS site for the specified period

V^i_{Dm} = Average speed at the mth detector of the ith TMS site for the specified period

F^i_{Dm} = Total volume at the mth detector of the ith TMS site for the specified period

n = Number of detectors at the ith TMS site (Martin 2003)

Equation 4-4 can be used to calculate speed for a specified period of time where weight is the ratio of total volume in time of t to total volume in time of T (Martin 2003).

Equation 4-4

$$V^i{}_T = \frac{\sum_{k=1}^{n} F^i{}_{tk} V^i{}_{tk}}{\sum_{k=1}^{n} F^i{}_{tk}}$$

Where:

$V^i{}_T$ = Weighted average speed at the ith TMS site for the specified period T
$V^i{}_{tk}$ = Average speed at the ith TMS site for the specified period t
$F^i{}_{tk}$ = Total volume at the ith TMS site for the specified period t
n = The number of t intervals included in the T (Martin 2003)

An alternate method of calculating speed is shown below:

Equation 4-5

$$SA = \frac{3600L}{TR} + D$$

SA = Average Travel Speed
L = Segment length (miles)
TR = Total Running Time for each segment (seconds)
D = Average stopped delay during PM peak hour traffic (seconds) (Sellsted)

9) *Travel Time* is the time takes to travel a measured distance on a segment or corridor. It is calculated using average speed over a segment of a given distance. The average five-minute speed is usually applied, as shown in Equation 4-6. The process is shown in Equations 4-6 to 4-9. Over a link, real time speed can be used to calculate the precise travel time (Martin 2003).

Equation 4-6

$$T_i(t) = \frac{L_i}{V_i(t)}$$

Where:
$V_i(t)$ = average speed in a five-minute interval at the ith TMS at time t when vehicles travel over the ith segment
L_i = the length of the ith segment holding the ith TMS, which can be derived from the adjacent TMSs' locations marked by milepost value (Martin 2003)

“Assuming $x_i, x_2, ... x_n$ as locations of n TMSs on a directional roadway, L_i is calculated as follows:

Equation 4-7

$$L_i = \frac{x_{i+1} - x_{i-1}}{2}$$

“The lengths of the first and last segments are:

Equation 4-8

$$L_i = (x_2 - x_1), \quad L_n = (x_n - x_{n-1})$$

“Equation 4-9 shows that travel times are aggregated over a set of links to find the total travel time *T* for an entire or specific section of a route” (Martin 2003).

Equation 4-9

$$T = \sum \frac{L_i}{V_i(t)}$$

10) *Reliability* is defined as:

- “The likelihood of a traveler’s expectations being met. Reliability is measured as the variability between the expected travel time (based on scheduled or average travel time) and the actual travel time (due to the effects of nonrecurrent congestion).
- The range of travel times experienced during a large number of daily trips.
- The impact of nonrecurrent congestion on the transportation system, estimated as a function of the variation in the duration, extent, and intensity of traffic congestion on a system” (Transportation Research Board, *NCHRP Synthesis 311* 2003).

Many techniques have also been reported for measuring reliability. It is generally measured in terms of the variability of travel time, characterized by the various travel times associated with a given trip. “The range of travel times can be obtained by calculating the mean and standard deviation of travel times within a sample. For example, an uncongested facility might have a trip time reliability of 12 to 15 minutes for 85% of all trips, whereas on a congested facility the reliability might be between 20 and 30 minutes.” This way of calculating reliability was used to study the benefits (travel time savings) of high-occupancy vehicle (HOV) lanes versus freeway main lanes. This method can be applied to a single roadways, corridors, and area wide networks, but should be used to compare travel times along one facility (Transportation Research Board, *NCHRP Synthesis 311* 2003).

A higher standard deviation in the sample travel time correlates to higher variability and therefore less reliability. When using equation 4-10 to calculate standard deviation, a large sample size should be used (Martin 2003).

Equation 4-10

$$s^2 = \frac{\sum (T_i - M)^2}{n-1}$$

Where,

s = the estimate of travel time standard deviation
T_i = the travel time of the ith travel crossing a specific route
M = the mean travel time of a set of samples
n = the number of sampling travels (Martin 2003)

Figure 4-4 contains an algorithm for calculating variability and reliability. Travel time and expected number of trips are input from TMS data (Martin 2003).

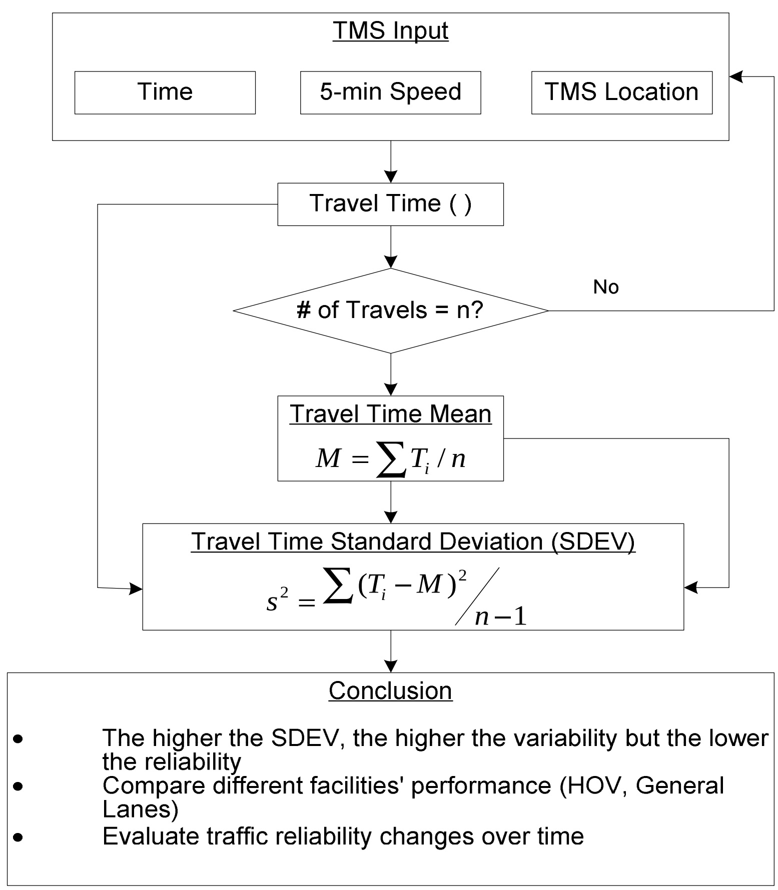

Figure 4-4: Traffic Variability and Reliability Algorithm (Martin 2003)

A reliability performance indicator, *R*, was theorized by Ikhrata and Michell. It is the probability that travel time will either meet or exceed the expected travel time, based on previous trips. Equation 4-11 shows how to calculate *R* using data from commuter surveys (Transportation Research Board, *NCHRP Synthesis 311* 2003).

Equation 4-11

$$R = 1 - (\%trips_{within} - \%trips_{exceed})$$

Where,

$\% \ trips_{within}$ = percent of trips in which users arrive at their destinations at the expected (average) travel time or less; and

$\% \ trips_{exceed}$ = the percent of trips in which users do not arrive at destinations within the expected (average) travel time

"A preliminary investigation of this methodology revealed that because the indicator is based on the average travel time, approximately one-half of the observations will always fall within the average value and one-half will exceed it. Using this methodology, the reliability performance indicator will always have a value in the range of 0.9 to 1.1." The index will increase with decreasing reliability (Transportation Research Board Synthesis 311 2003).

A "reliability buffer index" was established in the Texas Transportation Institute's *Urban Mobility Report: 2000*. The index represents "the difference between the average travel time and the 95th percentile travel time as the extra time that has to be budgeted for a trip compared with the average travel rate to define a reliability index" (Transportation Research Board, *NCHRP Synthesis 311* 2003).

Equation 4-12

$$Buffer\ Index\ (BI) = \frac{95th\ Percent\ Confidence\ Rate - Average\ Travel\ Rate}{Average\ Travel\ Rate} \times 100\%$$

Due to significant variability during peak hours, 2 minutes per mile should be added to the buffer (on top of the average travel time of 1.5 minutes per mile) (Transportation Research Board, *NCHRP Synthesis 311* 2003).

Reliability can also be measured as the difference between incident-related delay and nonincident-related delay using Equation 4-1 (Transportation Research Board, *NCHRP Synthesis 311* 2003).

How Florida Calculates Reliability

“The *Florida’s Reliability Method* report (Jackson et al. 2000) went further to derive a methodology for determining reliability from the Florida DOT’s definition of the reliability of a highway system as the percent of travel on a corridor that takes no longer than the expected travel time plus a certain acceptable additional time. In this context, it is necessary to define the three major components of reliability.

1. Travel time—The time it takes a typical commuter to move from the beginning to the end of a corridor. Because speed is determined along each segment as the traveler moves through the corridor, this travel time is a function of both time and distance. This is representative of the typical commuter’s experience in the corridor.
2. Expected travel time—The median travel time across the corridor during the time period being analyzed. The median is used rather than the mean so that the value of the expected travel time is not influenced by any unusual major incidents that may have occurred during the sampling period. These major incidents will be accounted for in the percentage of how often the travel takes longer than expected, but will not change the baseline to which that unusually high travel time is being compared.
3. Acceptable additional time—The amount of additional time (Δ), beyond the expected travel time, that a commuter would find acceptable during a commute. The acceptable additional time is expressed as a percentage of the expected travel time during the period being analyzed. Times 5%, 10%, 15%, and 20% above the expected travel time are currently being considered. However, Florida practice recommended that preference surveys be conducted to determine how much difference from the expected commute a traveler would find acceptable.

“The threshold when travel exceeds the acceptable additional time beyond the expected travel time is obtained using the following equation:

Acceptable $TT = x + \Delta$

where

x = the median travel time across the corridor during the period of interest; and
Δ = an additional travel time estimated as a percentage of the median travel time during the period of interest or value, used to establish the additional time beyond the expected travel time that a traveler would find acceptable.

“The percent of reliable travel is calculated as the percent of travel on a corridor that takes no longer than this acceptable travel time. A comparative analysis was conducted using traffic flow data for the following three study corridors: (1) I-95 in Jacksonville, (2) I-95 in Broward County, and (3) I-4 in Orlando. Two test corridors were also included in the project. The first test corridor was I-95 from south of Hallandale Beach Boulevard in Broward County to north of Yamato Road in Palm Beach County. Data for this corridor were collected as part of a 1999 Interstate Traffic Data Survey. The second test corridor was a 23-mi segment of I-405 in Seattle, Washington. The reliability results suggest that the Florida Reliability Method is well suited for measuring reliability because it characterizes reliability as an indicator of how well conditions on the corridor meet travelers' expectations by establishing an acceptable travel time unique to the corridor. This definition matches well with the reliability definitions provided by operations researchers and used in other commercial transportation applications such as aviation (ontime arrivals), rail (on-time arrival), and integrated logistics (on-time or just-in-time delivery). Other methods describe the variability of travel time but do not report directly on reliability from this perspective. The following recommendations were made regarding data collection for reliability measurement:

• For the calculation of reliability using the Florida Reliability Method, the acceptable additional time should be based on a fixed percentage of 15 or 20% of the expected travel time. However, it is recommended that preference surveys be conducted to determine how much difference from the expected commute a traveler would find acceptable.

• Reliability should be measured for a consistent peak hour (such as 5 to 6 p.m.) rather than the peak period for a corridor. This allows comparisons between facilities, and also enables annual monitoring of reliability on the same facility, because the peak period may change from year to year.

• The interval for collecting speed and volume data should be less than the travel time under free-flow conditions.

• The optimum data collection period for the reliability measurement is a 6-week period using data collected at intervals of 5-min or less based on the travel time under free-flow conditions as noted above.

• Data collected over a 4-week period at 15-min intervals is the minimum recommended to provide an adequate sample size" (Transportation Research Board Synthesis 311 2003).

Box 4-3: How Florida calculates reliability

11) *Travel Time Index* (TTI) is "the ratio of peak period travel time to free-flow travel time. It represents the ease of getting to a destination." TTI can range from 1 to infinity, where a large number indicates congestion. For example, a TTI of 1.3 means that a trip taking 10 minutes during off-peak hours will take 13 minutes during peak hours. TTI can be applied to segments of the roadway or the entire system. Equation 4-13 shows how TTI is calculated (Martin 2003).

Equation 4-13

$$TTI = \frac{\sum \frac{l_i}{V_i(t)}}{\sum \frac{l_i}{f_i}}$$

Travel rate index is the increase in travel time and is calculated in the following ways (Transportation Research Board Synthesis 311 2003):

Equation 4-14

$$\frac{\textit{Travel Time Under Congested Conditions}}{\textit{Travel Time Under Uncongested Conditions}}$$

Equation 4-15

$$\frac{\dfrac{60/Speed_{Freeway}}{60/Freeflow\ Speed_{Freeway}} \times VMT_{Freeway} + \dfrac{60/Speed_{Arterial}}{60/Freeflow\ Speed_{Arterial}} \times VMT_{Arterial}}{VMT_{Freeway} + VMT_{Arterial}}$$

Chapter 5 will provide a detailed view of important data requirements and concerns related to these performance measures mentioned in this chapter. The next chapter serves as a bridge between Chapter 4 on Agency Goals and Performance Measures and Chapter 6 on Performance Monitoring, Evaluating, and Reporting.

References

Battelle, Texas Transportation Institute, and Cambridge Systematics, Inc., *State of the Practice for Traffic Data Quality,* Federal Highway Administration, December 2002

Cambridge Systematics, Inc., *NCHRP Project B8-32(2)A: Multimodal Transportation: Development of a Performance-Based Planning Process,* Transportation Research Board, National Research Council, 1999

Federal Highway Administration, *Breakout Session Summary,* Accessed July 2005, www.fhwa.dot.gov/freightplanning/brkout.ppt

Florida's Mobility Performance Measures Program, Presented at the Conference on Performance Measures to Improve Transportation Systems and Agency Operations, Irvine, CA, http://www.dot.state.fl.us/planning/statistics/mobility measures/mmpresentation.pdf, 2000

Houston TransStar, Greater Houston Transportation and Emergency Management Center, *About Houston TransStar,* Accessed July 2005, http://www.houstontranstar.org/about_transtar/

Hudson Valley Transportation Management Center, *Hudson Valley Transportation Management Center Programs*, Accessed July 2005, http://www.hudsonvalleytraveler.com/perl/HVTMCPrograms.pl#Overview

ITS Decision, *Detection Algorithms,* http://www.calccit.org/itsdecision/serv_and_tech/Traffic_management/Incident_management_traffmagt/Incident_detection_traffmagt/detection_algorithms_traffmagt/detection_algorithms_summary_traffmagt.htm, 2003

Martin, Peter T., University of Utah Traffic Lab, *Automated Data Collection, Analysis, and Archival,* http://www.ndsu.nodak.edu/ndsu/ugpti/MPC_Pubs/html/MPC03-153/, November 2003

Neudroff, Lois G.; Randall, Jeffery E., P.E.; Reiss, Robert, P.E.;Gordon, Robert, P.E., *Freeway Management and Operations Handbook (Report No. FHWA-OP-04-003)*, September 2003

New York State Department of Transportation, Accessed May 2005, http://www.dot.state.ny.us/

Ohio Department of Transportation, Accessed May 2005, http://www.dot.state.oh.us/

Ohio Department of Transportation, Accessed May 2005, http://www.oregon.gov/ODOT/

PB Farradyne, *Traffic Incident Management Handbook*, Federal Highway Administration, November 2000

Pekow, Charles. *Are MPOs Giving Bicycling Its Due? Accessed July 2005. http://www.bikexchange.com/su04f1.htm*

Rhode Island Department of Transportation, Accessed May 2005, http://www.dot.state.ri.us/

San Antonio Bexar Country Metropolitan Transportation Planning Organization. Accessed July 2005, http://www.sametroplan.org/, updated July 8, 2005

Schrank, David and Lomax, Tim. The 2003 Annual Urban Mobility Report, Texas Transportation Institute, September 2003

Sellsted, Thomas E., *Travel Speed Study of Urban Streets Using GPS & GIS,* Yakima Washington Information Systems and Traffic Engineering Divisions, Accessed July 2005, http://www.ci.yakima.wa.us/gis/doc/SNC2004%20-%20Travel%20Speed%20Study.ppt

Sreedevi, Indu, *ITS Decision--Services and Technologies--Traffic Management Centers,* California Center for Innovative Transportation at the University of California at Berkeley and Caltrans, Accessed July 2005 http://www.calccit.org/itsdecision/serv_and_tech/Traffic_management/TMC/tmc_summary.html, 2003

Transportation Research Board, *NCHRP Synthesis 311,* Washington D.C., 2003

Transportation Research Board, *NCHRP Synthesis 318*, *Safe and Quick Clearance of Traffic Incidents*, 2003

Transportation Research Board, *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System*, Washington D.C., 2003

TransTech Management, Inc., *Strategic Performance Measures For State Departments Transportation: A Handbook For CEOS And Executives,* June 2003, Accessed: February 2005, http://downloads.transportation.org/Quality

Utah Department of Transportation, Accessed April 2005, http://www.dot.state.ut.us/

Virginia Department of Transportation, Accessed April 2005, www.vdot.virginia.gov/

Washington State Department of Transportation (WSDOT), *Spokane Regional Transportation Management Center begins operations,* Accessed July 2005, *http://www.wsdot.wa.gov/regions/Eastern/ViewNews.cfm?file=20020722Spokane%20Regional%20Transportation%20Management%20Center%20begins%20operations.htm*, 2005